EARTH SCIENCE ENTERPRISE APPLICATIONS STRATEGY *for* 2002-2012

National Aeronautics and Space Administration

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Preface

The Applications Program within the Earth Science Enterprise (ESE) of the National Aeronautics and Space Administration (NASA) was created in 1998 to accelerate and expand the process that brings NASA Earth system science results to bear on the problems that confront our citizens. The Applications Program serves the Earth Science Enterprise and the Nation by benchmarking practical uses of NASA sponsored ***observations*** from remote sensing systems and ***predictions*** from scientific research for decision makers. NASA implements projects through partnerships with public, private, and academic organizations that are a priority to citizens of our nation and that can be enhanced by NASA ESE results. These partnerships focus on innovative approaches for using Earth science information to provide decision support that can be adapted in applications nationwide.

The ESE Applications Strategy builds on the strategies and results of the ESE Research Program and of the ESE Technology Program. The focus of the Earth Science Enterprise is on answering one overarching Earth science question and five related science questions:

How is the Earth system changing, and what are the consequences for life on Earth?

- *How is the global Earth system changing?*
- *What are the primary causes of change in the Earth system?*
- *How does the Earth system respond to natural and human-induced changes?*
- *What are the consequences of change in the Earth systems for human civilization?*
- *How can we predict future changes in the Earth system?*

The ESE Technology Program supports the ESE Research Program by developing advanced technology and tools associated with orbital and sub-orbital missions using innovative remote sensing and information technologies. ESE currently provides measurements from Terra, QuikSCAT, Landsat 7, Jason, and other missions.[1] ESE launched the Aqua mission in May 2002 and plans to launch the Aura mission in 2004. Measurements may also be supported through data buys (e.g., ocean color imagery from SeaWiFS, high resolution optical imagery from IKONOS, QuickBird, and other private-sector satellites, and land cover data from the Landsat Data Continuity Mission).

This document describes the direction of the Earth Science Enterprise Applications Program for the period from 2002 through 2012. Building on the NASA vision and ESE mission, the document includes the Program mission and goals. Program planning strategy and the concept of operations to implement the strategy are described. The document also identifies performance measures by which to evaluate the program. The vision, mission, goals, and strategy are consistent with higher-level guidance, and the plan is also consistent with requirements of other Federal agencies to meet their goals and objectives in support of U.S. national policy. Also included in this document are appendices that define key terms, present relevant directives, and provide references.

[1] Detailed mission information is available at www.earth.nasa.gov.

NASA EARTH SCIENCE ENTERPRISE APPLICATIONS STRATEGY FOR 2002-2012

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1.0 Introduction

1.1 The NASA Vision and Mission

In April 2002, Sean O'Keefe, the NASA Administrator, unveiled a vision and a mission that will carry the agency forward into the 21st century (O'Keefe, 2002b). The new NASA vision has been articulated as being

To improve life here,

To extend life to there,

To find life beyond.

The new mission statement is:

To understand and protect our home planet

To explore the universe and search for life

To inspire the next generation of explorers

...as only NASA can.

Administrator O'Keefe further expanded on the first sentence of this statement in April 2002 to explain NASA's mission includes the following:

- Understanding the Earth's system and its response to natural and human-induced changes.
- Investing in technologies and collaborating with others to improve the quality of life and to create a more secure world (O'Keefe, 2002a).

Earth system science is the first element of this new vision and mission, and it builds on more than a decade of scientific and technological advances. Over the past 15 years, the Earth Science Enterprise has defined a program of research in collaboration with the scientific community that was intended to increase our knowledge of the Earth as a system of interactive processes. The ESE has a mission to develop a scientific understanding of the Earth system and its response to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations.

To accomplish this mission, the ESE has established a science goal to "observe, understand, and model the Earth system to learn how it is changing, and the consequences for life on Earth" (NASA, November 2002). ESE missions and research seek to answer questions related to the Earth's variability, the forces acting on it, the Earth's response, the resulting consequences, and improved predictions.

Specific elements of the ESE's contributions to the NASA vision and mission are as follows:

- Providing enhanced and improved space-derived observation data to improve the lead-time and accuracy of weather predictions.
- Providing Federal agencies with appropriate data and information about Earth science (e.g., weather, climate, and natural hazards) to enhance existing and to develop new products and services that can be delivered through state, local, and tribal organizations to serve the Nation's citizens.
- Providing critical Earth science observations, data assimilation, research, and modeling in support of weather, climate, and natural hazard research needs for decision support and policy-making in both the public and private sectors.

The Earth Science Enterprise (ESE) Applications Program contributes to the NASA vision by enabling individuals and organizations in the public and private sectors to routinely deliver and use Earth science information that saves lives, that improves the quality of life, and that saves resources through improved decision making.

The ESE works with partners in government agencies, in the private sector, and in academia to establish America as an international benchmark for effective applications of Earth science information and related models.

1.2 Earth Science Enterprise Heritage and Plans

Since 1960, NASA has developed space-based missions to provide observational parameters enabling the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) National Weather Service to predict the weather. NASA continues to build upon its experience and heritage working with NOAA to deliver space borne observations that are used in computer models to provide weather predictions. NASA technology advancements in building weather instruments, coupled with improved capabilities for weather prediction modeling, contribute to the current capability of three-day forecasts with associated accuracies on the order of 93 percent. Since 1972, NASA has provided the Landsat satellites for mapping and monitoring of land cover and land use. Landsat continues to set the standard for global land observations, providing decision support to the U.S. Geological Survey (USGS), to the U.S. Department of Agriculture (USDA), to the National Imagery and Mapping Agency (NIMA), and to organizations around the world.

Over the next 10 years, NASA's Earth Science Enterprise, in cooperation with its partnering agencies, plans to increase the lead-time and accuracy of forecasts in weather, climate, and natural hazards (see Table 1). Such predictive capabilities are tightly linked with implementation functions in partnering operational agencies. Increases depend on scientific research in climate variability, atmospheric composition, solid Earth and natural hazards, and changes in water cycle, carbon cycle, and ecosystems. By achieving these increases, NASA will contribute to providing a sound scientific basis for national policies and economic decision-making concerning resource management and global change (National Science and Technology Council, 2001, p. 2).

Table 1 – ESE Plans for Predictive Capabilities

	Today	Goals For 2010
Weather	• 3 day forecast at 93%* • 7 day forecast at 62%* • 3 day rainfall forecast not achievable • Hurricane landfall +/- 400 km at 2-3 days • Air quality day by day	• 5 day forecast at >90% • 7-10 day forecast at 75% • 3 day rainfall forecast routine • Hurricane landfall +/- 100 km at 2-3 days • Air quality forecast at 2 days
Climate	• 6-12 month seasonal prediction experimental; achieved an understanding of El Nino mechanics • Decadal climate prediction with coarse models and significant uncertainties in forcing and response factors	• 6-12 month seasonal prediction *routine*; 12-24 months experimental • 10 year climate forecasts experimental; moderate to high confidence in forcing and response factors
Natural Hazards	• Centimeter-level measurement of land deformation • Accurate characterization of long-term tectonic motions, but no short-term earthquake forecast capability • Accurate characterization of volcanic activity, but no long-term prediction accuracy	• Continuous monitoring of surface deformation in vulnerable regions in with millimeter accuracy • Improved temporal dimensions of earthquake & volcanic eruption forecasts • Improved post-eruption hazard assessment
**Accuracy refers to sea level pressure forecasts over Northern Hemisphere during winter*		

Source: ESE Overview Presentation, 2001

NASA ESE supports scientific research and policy by providing critical Earth system science observations, data assimilation, research results, and modeling as part of the U.S. Global Change Research Program. NASA's unique space-based Earth observations also serve essential global change and solid Earth and natural hazard research needs of the National Science Foundation, the USDA, the Department of Defense (DOD), the Department of Energy (DOE), the Department of the Interior (DOI), the Environmental Protection Agency (EPA), and the Department of Health and Human Services and the National Institutes of Health (HHS/NIH). NASA research and observations are employed in international scientific assessments by such organizations as the World Meteorological Organization, the Food and Agriculture Organization of the United Nations, the United Nations Environment Program, and the Intergovernmental Panel on Climate Change. The need for informed decision making of organizations is expected to grow substantially in the coming decade, thus providing additional opportunities for applications of NASA remote sensing technologies, data, and programs.

NASA also serves an operational community with data and information about the Earth system. While the heritage of NASA Earth science has been with NOAA's weather and climate monitoring organizations that serve the Nation's weather forecasters and broadcasters, other operational users require data and information integrated and packaged into "systems" to deliver reliable products and services to citizens. NASA identifies organizations with the appropriate information infrastructure to apply the results of NASA's Earth science research to help manage forest fires, coastal environments, agriculture, infectious disease impacts, aviation safety, and hurricane

forecasting. Such national and international needs will continue to evolve, and the Earth Science Enterprise Applications Program will enable NASA contributions to help meet these evolving needs. To keep pace with these evolving needs, the ESE plans to provide annual updates to this strategy with comprehensive reviews through the National Research Council on a 3-year cycle.

To demonstrate the applicability of evolving Earth system science knowledge, NASA works with USDA, NOAA, USGCRP, USGS, DOD, DOE, DOI, EPA, HHS/NIH, the Federal Emergency Management Agency (FEMA), the U.S. Army Corps of Engineers, NIMA, the Department of State, the Federal Aviation Administration, other Federal-level agencies, and with a variety of state, local, and tribal organizations. NASA and its partners extend research and developments in observations, processing, data assimilation, and modeling to serve national priority needs for a range of spatial information requirements for decision support.

1.3 Earth Science Enterprise Applications Program Mission

An important aspect of the Earth Science Enterprise is to ensure that results of ESE research and technology produce positive impacts for the citizen's of the world. Consistent with the ESE mission, the Earth Science Enterprise Applications Program mission is as follows:

Expand and accelerate the realization of societal and economic benefits from Earth science, information, and technology.

Implementing the Earth Science Enterprise Applications Program mission and realizing societal and economic benefits requires NASA and its partners in federal agencies, in national-level organizations, in private-sector organizations, and in academia to focus on solutions that are citizen-centered, results-oriented, and market-driven. To accomplish its mission, the Earth Science Enterprise Applications Program provides a bridge between ESE research and operational solutions. As shown in Figure 1, *operational solutions and applications* that benefit the public are enabled by systematically relating appropriate results from measurements and *applied research* in weather, global climate change, and natural hazards. Applied research, in turn, is enabled by *basic*

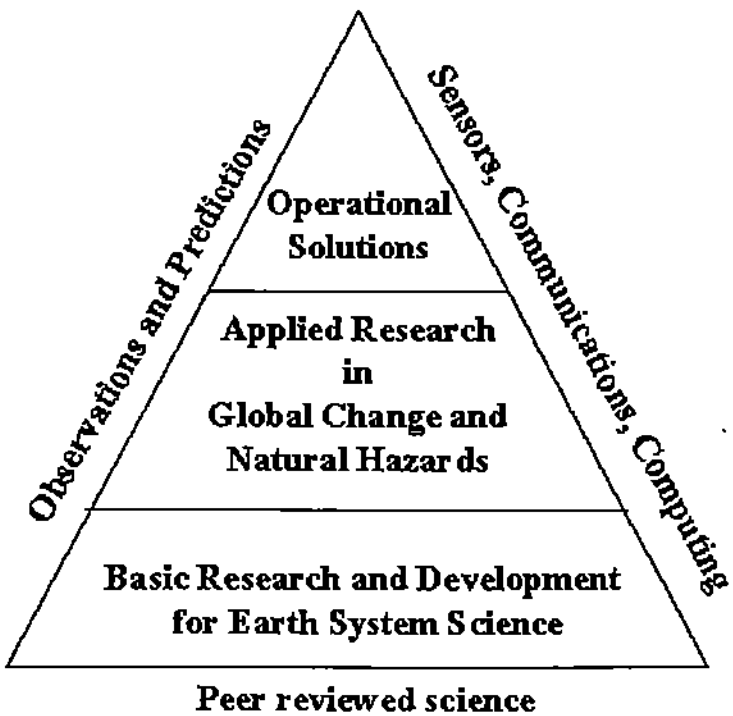


Figure 1 – Earth Science Pyramid

research and technology developments in Earth science. The relationship among basic research and development, applied research, and operational solutions is dynamic and iterative. NASA evaluates operational and commercial solutions providing *observations, communications, and computing capabilities* for their capacity to support both basic and applied research in Earth science. Peer-reviewed research from the biogeophysical sciences establishes the foundation for basic and applied research in Earth system science and ultimately its application through operational solutions.

1.4 Earth Science Enterprise Applications Program Goals

While recognizing the inevitability of changing circumstances, the Earth Science Enterprise Applications Program mission is focused on specific goals to support the NASA vision and the ESE mission. These goals are broadly defined to be flexible and effective in responding to changing circumstances, yet consistent enough over time to encourage the long-term growth of expertise and understanding of user needs. The overarching goal for the Earth Science Enterprise Applications Program is *to bridge the gap between Earth system science research results and the adoption of data and prediction capabilities for reliable and sustained use in decision support.* The architecture to accomplish this is shown in Figure 2. Related goals include the following:

- Simplify and integrate the use of Earth system science data and prediction results for adoption in national applications that enable decision-making.
- Enhance the availability, interoperability, and utility of ESE and U.S. private sector datasets, communications, and computing and modeling capabilities as inputs to serve specific applications and research.
- Produce prototypes, guidelines, assessments, and documentation of project results that are citizen-centered, results-oriented, and market-driven.
- Enable the project results to serve as benchmarks for policy and operational uses that benefit citizens through our Federal, state, local, tribal, and private sector partners.

As part of a systems engineering approach to achieving its goals, the Earth Science Enterprise Applications Program will use "reverse engineering" techniques to assess user needs for improved decision support and will relate those needs to ESE observations and models with potential to improve decision-support solutions (Figure 3). Limitations or shortfalls in available research results for improving decision support will be feed back to the ESE and its related technology development programs.

The success of the Earth Science Enterprise Applications Program will be based on the degree to which it has evaluated, verified and validated, and benchmarked the capacity of ESE results to serve national applications through improved decision-support solutions.

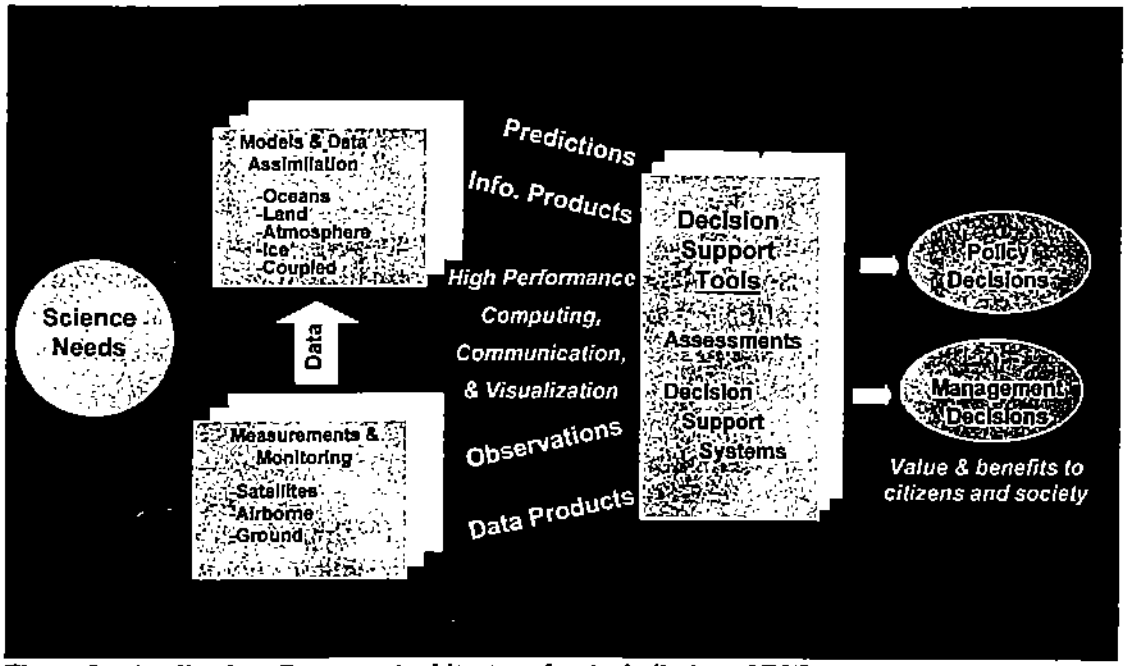


Figure 2 – Applications Program Architecture for Assimilation of ESE Results to Affect Societal Benefits

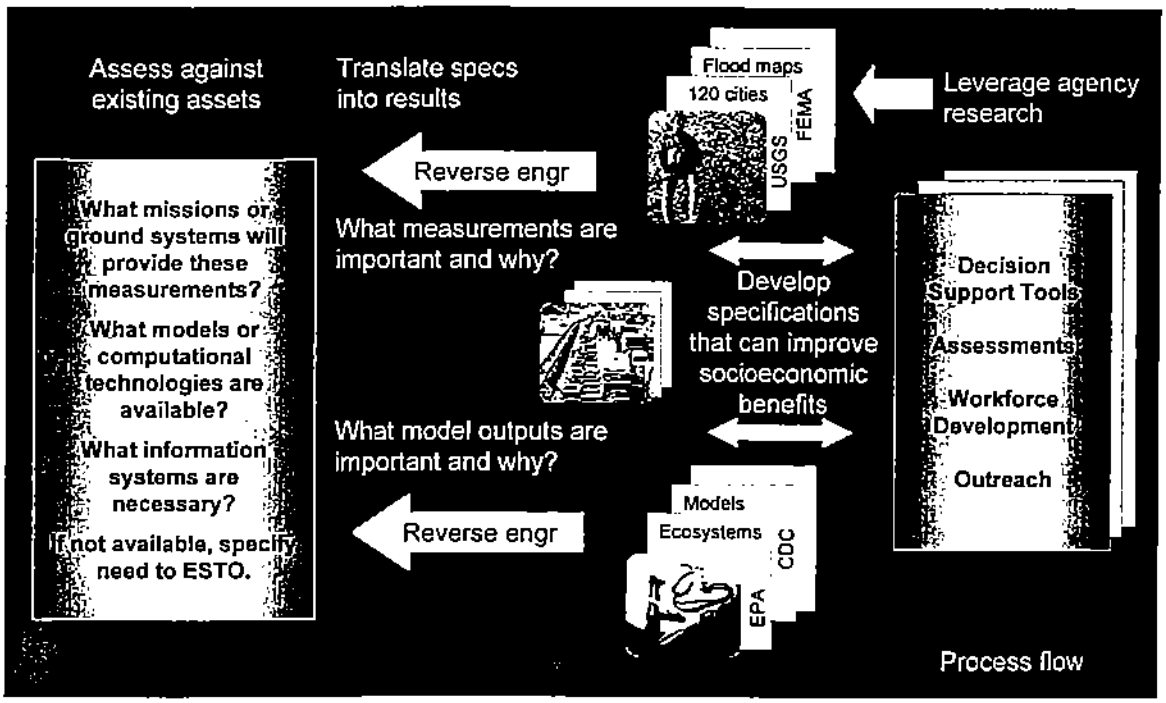


Figure 3 – Reverse Engineering Paradigm

2.0 Earth Science Enterprise Applications Program Planning Strategy

The Earth Science Enterprise Applications Program planning strategy for accomplishing its mission and goals focuses on identifying and selecting application themes with the highest priority in fulfilling national needs and opportunities. In this context, national needs include initiatives identified by the Executive and Legislative branches of the Federal government and the national programs conducted in support of the missions of Federal agencies, and in concert with state, local, and tribal organizations. There is a wide range of potential applications of ESE data and predictive capabilities. To address systematically application priorities in the national interest, ESE conducts its strategy for program planning in three stages.

2.1 Identification of Candidate National Applications

A National Application is a thematically focused program in which partners with a national scope own and operate decision support tools for their policy, analysis, and management responsibilities. The National Application must clearly be a priority to citizens of our nation and have the potential for enhanced decision making by assimilating NASA ESE results. Examples of National Applications are Air Quality, Energy Forecasting, and Homeland Security.

NASA ESE leadership[2] identifies candidate applications in terms of their potential to serve existing national needs. The Earth Science Enterprise Applications Program selects National Applications based on the extent to which they exhibit the following characteristics:

- Identified as a national priority by the Executive and/or Legislative branches
- Relevant to national program(s) of one or more Federal agencies
- Requirements validated (by other agencies) with the potential to be served by Earth science and remote sensing research and development results
- Significant societal and/or economic value in terms of clearly defined metrics, such as quality of life improvements, potential lives saved, and economic or resource savings

The Earth Science Enterprise Applications Program profiles candidate applications projects using a systems-level "roadmap" showing relationships among Earth system science, remote sensing activities, and related technologies being conducted by ESE and other organizations, potential applications, and desired outcomes and expected impacts. NASA ESE management works with objective third parties to conduct independent assessments of candidate National Applications using pre-established guidelines and metrics.

[2]ESE leadership consults with the Earth System Science and Applications Committee (ESSAAC) and considers national priorities identified by U.S. National Academy of Science in identifying candidate national applications.

2.2 Prioritization/Selection of National Applications

The Earth Science Enterprise Applications Program evaluates candidate applications projects based on criteria that are consistent with the ESE Research Strategy. Reviews of candidate applications conform to the schedule associated with the Federal budget process in terms of preparing plans for out-year activities. The criteria for prioritizing National Applications (listed in order of priority) are:

- **Socio-Economic Value**—an assessment of prospective societal and economic benefits e.g., public safety and health, national security, environmental quality, economic threats and opportunities, populations affected, and related factors. The basis of the assessment is an independent value/benefit analysis that estimates the extent of likely societal or economic value.
- **Application Feasibility**— an assessment of user readiness to adapt applications of Earth science and technology to operational environments. The time required to develop and implement an application is considered in the review. A threshold for application feasibility is the identification of a specific information mandate or discrete decision support system that benefits specifically from knowledge, data, and/or technology defined and proposed for development by an application.
- **Response to Oversight**—review of programs or projects that the Administration and/or Congress direct NASA to support with respect to ESE mission, goals, and objectives. These sources of Executive or Congressional direction may include Executive Office of the President directives, legislation, regulation, budget requirements, and other official guidance (see Appendix C).
- **Appropriate for NASA**—the extent to which an application makes productive use of the unique or complementary assets and capabilities of NASA, and could not be performed as effectively by other government agencies or private entities.
- **Partnership Opportunity**—the extent to which applications can be carried out in collaboration with partners, especially U.S. Federal agencies. The objective of partnerships is to leverage resources and establish commitment by public and private partners to the effective transition of ESE results to operational uses.
- **Science and Technology Readiness**—the extent to which science and/or technology results can be developed to a level of maturity necessary to demonstrate operational use and that public and private institutions have the knowledge/technology infrastructure to adopt the application.
- **Program Balance**—the need to systematically balance the applications investment "portfolio" among application areas (e.g. community growth, environmental assessment) and among the types and levels of investment risk.
- **Cost/Budget Context**—the evaluation and analysis of costs, constraints and directions of the ESE with regard to available budgets and funding profiles. The Earth Science Enterprise Applications Program seeks to ensure that the financial risk of a project is acceptable and balanced with the potential for cost savings or improved user decision-making.

From the set of prioritized National Applications, NASA makes decisions on which to include in the investment portfolio for each fiscal year budget based on funding availability. NASA applies the same criteria (in reverse order, starting with Cost/Budget Context) to evaluate the capacity for the Program to conduct the prioritized applications.

2.3 Identification/Selection of Projects for National Applications

In implementing individual projects for a National Application, the Earth Science Enterprise Applications Program establishes linkages between available science and technology capabilities and the specific application requirements. To define the linkages, NASA works with its partner(s) to develop a project plan and performance specifications describing a systematic approach of the necessary steps to benchmark the viability of the application for sustainable or operational use by a partnering organization (i.e., evaluation through reverse engineering). This stage identifies the appropriate approaches and organizations to fill the technical and/or business gaps identified in the project plan.

NASA ESE addresses the requirements delineated in the project plan to fill the gaps with systems engineering support and solicitations for projects that provide opportunities for the public, academic, and private sector communities to contribute solutions. NASA ESE reviews the proposals received in response to the solicitations using the same priority criteria described above. NASA ESE compiles documentation for all phases of the implementation of a project for a National Application and makes the documentation of results and processes available for public benefits.

Examples of ESE projects that benchmark the capacity of the ESE to produce societal benefits include the following:

- NASA is working in collaboration with the U.S. Forest Service to integrate MODIS imagery into a wildfire management decision support system for disaster management applications.
- The Tropical Rainfall Measuring Mission TRMM is a joint mission between NASA and the National Space Development Agency (NASDA) of Japan to monitor and study tropical rainfall and the associated release of energy. Such events help to power the global atmospheric circulation shaping both weather and climate around the globe, including catastrophic events, such as hurricanes and typhoons. The TRMM has applications for disaster management, air quality, water management and conservation, aviation safety, public health, and invasive species management.
- NASA and the National Oceanic and Atmospheric Administration (NOAA) are partners on the SeaWinds/QuikSCAT mission. The SeaWinds instrument onboard NASA's Quick Scatterometer (QuikSCAT) satellite is a specialized microwave radar that measures near-surface wind speed and direction under all weather and cloud conditions over Earth's oceans. To study the potential impact of scatterometer data on hurricane prediction, numerical forecasts of Hurricane Cindy in August 2000 were generated with and without SeaWinds scatterometer observations from QuikSCAT. Both magnitude and displacement errors were

substantially reduced when QuikSCAT scatterometer observations were incorporated into the forecasts; in this study, the 60-hour forecasts that used QuikSCAT data were as accurate as the 24-hour forecasts generated without these data (Atlas et al., 2002; Figure 4).

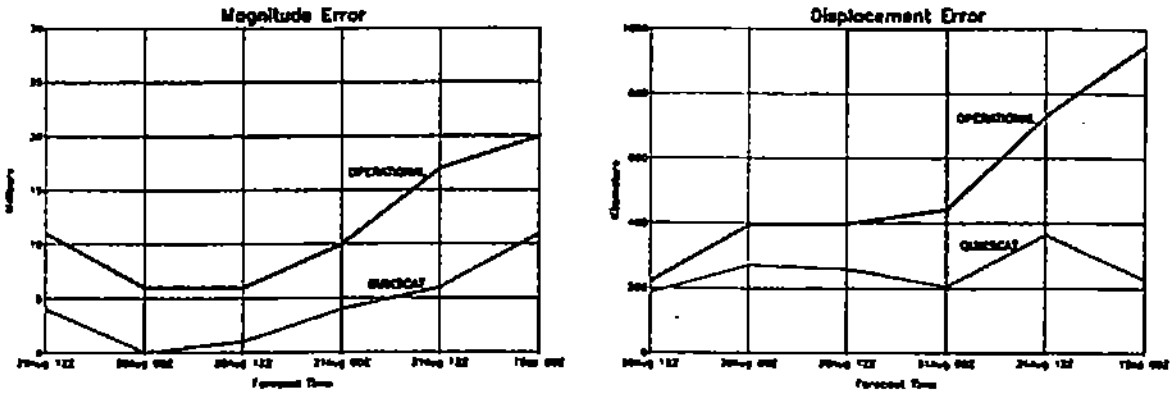


Figure 4 – Accuracy of 12 - 72 hour forecasts for Hurricane Cindy generated with (QuikSCAT - green) and without (Operational – red) scatterometer observations.

3.0 Concept of Operations

This section describes the Earth Science Enterprise Applications Program management and review structure, Earth Science Enterprise Applications Program implementation, partnership framework, and individual project implementation.

3.1 Earth Science Enterprise Applications Program Management Review

The Earth Science Enterprise Applications Program falls under the management of the Applications Division of the Office of Earth Science at NASA Headquarters. The Applications Division provides policy guidance and expertise on public/private partnerships, on collaboration between Federal agencies and research institutions, on research to operations transitions, and on science and technology applications to meet national needs and goals. The Applications Division conducts program planning and analysis to identify and to prioritize new target applications and to solicit and to select new applications, projects, and partners.

The ESE's Office of the Associate Administrator is responsible for the overall performance of the Earth Science Enterprise Applications Program, and this office reviews the Program routinely. The Associate Administrator periodically calls for an independent review of the Earth Science Enterprise Applications Program by the National Research Council. The ESE's Earth System Science & Applications Advisory Committee (ESSAAC) reviews the Earth Science Enterprise Applications Program on a semi-annual basis, using the performance evaluation points in Section 4 and the priority criteria identified in Section 2.

Two Federal government offices under the Executive Office of the President periodically review the Earth Science Enterprise Applications Program. The Office of Science & Technology Policy (OSTP) reviews the Program to assess its contributions to Administration priorities and to the missions of other Federal agencies. The Office of Management and Budget (OMB) reviews the Program to assess its compliance with budgetary structure, accountability, and the Administration's direction. In addition, Congress reviews the Earth Science Enterprise Applications Program periodically on its performance in support of legislative branch priorities.

3.2 Earth Science Enterprise Applications Program Implementation

The Earth Science Enterprise Applications Program develops solicitations, often in partnership with one or more Federal agencies, to provide opportunities for the public, academic and private sectors to compete to provide the applied research, products, and services required to accomplish the applications. The ESE Application Division coordinates the necessary leadership and expertise to implement the Earth Science Enterprise Applications Program and leverages Agency resources in such areas as decision support systems, analytical and predictive modeling, data distribution and handling systems, remote sensing systems, standards, and interoperability. The Applications Division works in collaboration with NASA Centers to develop solicitations and plans for accomplishing priority applications.

3.3 Earth Science Enterprise Applications Program Framework

The Earth Science Enterprise Applications Program Framework consists of projects following a spatial information cycle[3] that completes one cycle when partners incorporate NASA Earth science data into real-world applications. As illustrated in Figure 5, this cycle includes phases that encompass NASA's role in remote sensing and the application of remote sensing data and products to decision-making.[4] Starting from the left side of the cycle in Figure 5 and moving counterclockwise, data are *tasked* based on decision support tool needs and acquired from a variety of public and private sector **data measurement systems**, such as NASA's Earth Observing System (EOS) and commercial imaging systems, and *processed* to develop a set of **data products based on standards** for format and interoperability. The data products or predictions are then *exploited* by transforming remote sensing data and information into knowledge. **Data handling systems** enable effective *dissemination* of information products and knowledge to decision-makers to get the right information to the right place at the right time. Information products serve national-level decision support tools, resulting in societal and economic benefits. The NASA EOS Data Information System (EOSDIS) is an example of this phase of the cycle. Different organizations may manage different elements of the cycle. However, few organizations have the mandate to collaborate and integrate all of the elements to support decision-making through to applications in **decision support systems**. The Earth Science Enterprise Applications Program administers its program portfolio to bridge gaps between the elements in this cycle for applications in the national interest.

A result from following the spatial information cycle framework is that the Earth Science Enterprise Applications Program provides a bridge between the ESE's **research domain** and the **operational domain** of the public and private sectors. NASA ESE is focused on delivering results from the research domain of this cycle and has the benefit of administering all of the elements of the cycle within the NASA. NASA ESE extends discrete research results (such as global land use land cover maps, EOSDIS capabilities, and predictive analysis of wildfire behavior) to applications enabling end-to-end solutions working with partners in all four of the elements. If the reverse direction of the spatial information cycle framework is followed (i.e., from the operational domain to the research domain), then it can be seen how NASA may evaluate discrete capabilities deployed in the operational domain (such as higher resolution remote sensing systems, high-bandwidth communications systems, and high-speed computers) for use in supporting Earth system science research.

[3]NIMA refers to this cycle as TPED (tasking, processing, exploitation, and dissemination).

[4]NIMA and the United States Imagery and Geospatial Information Systems (USIGS) also use this cycle as the framework for their programs.

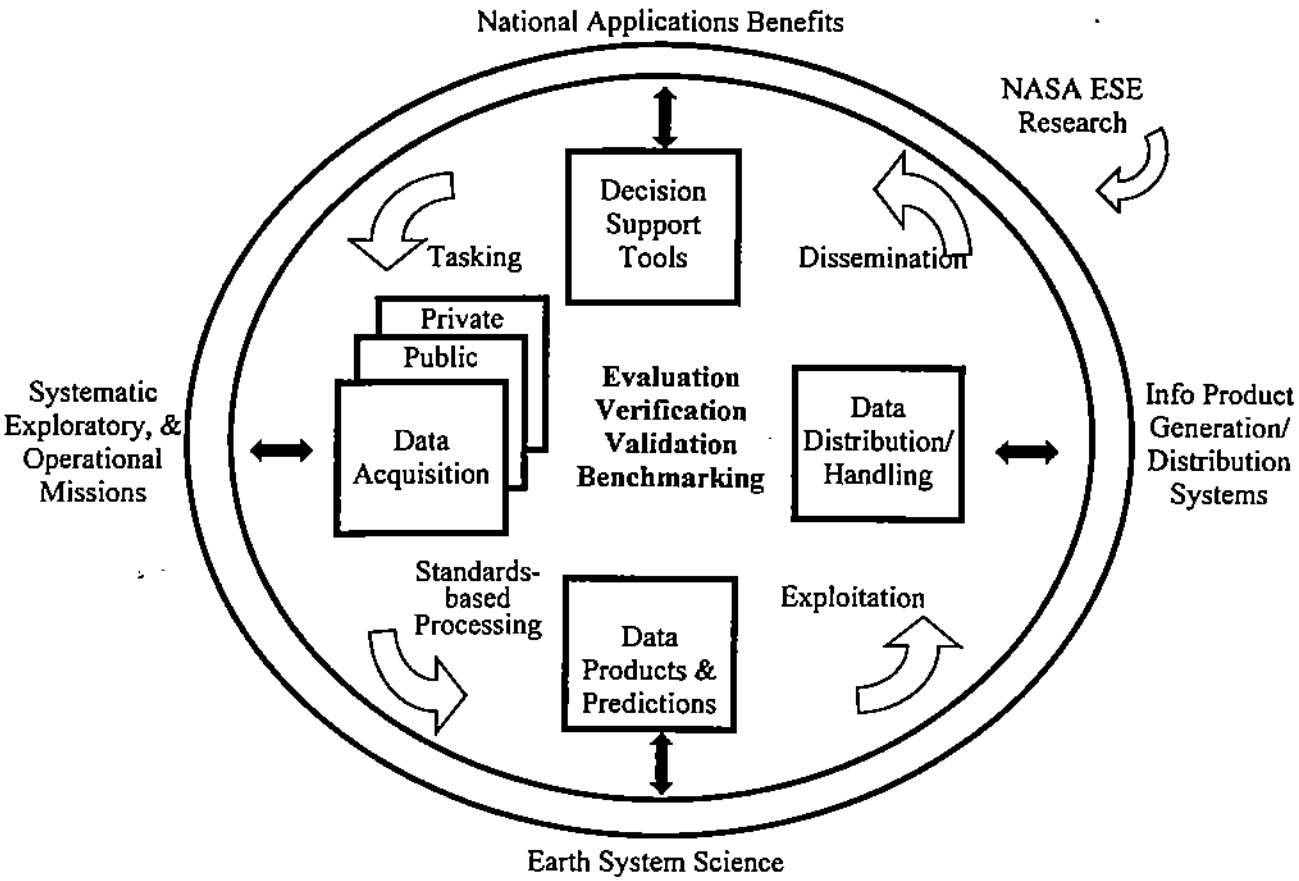


Figure 5 – Spatial Information Cycle

3.4 Project Development and Implementation

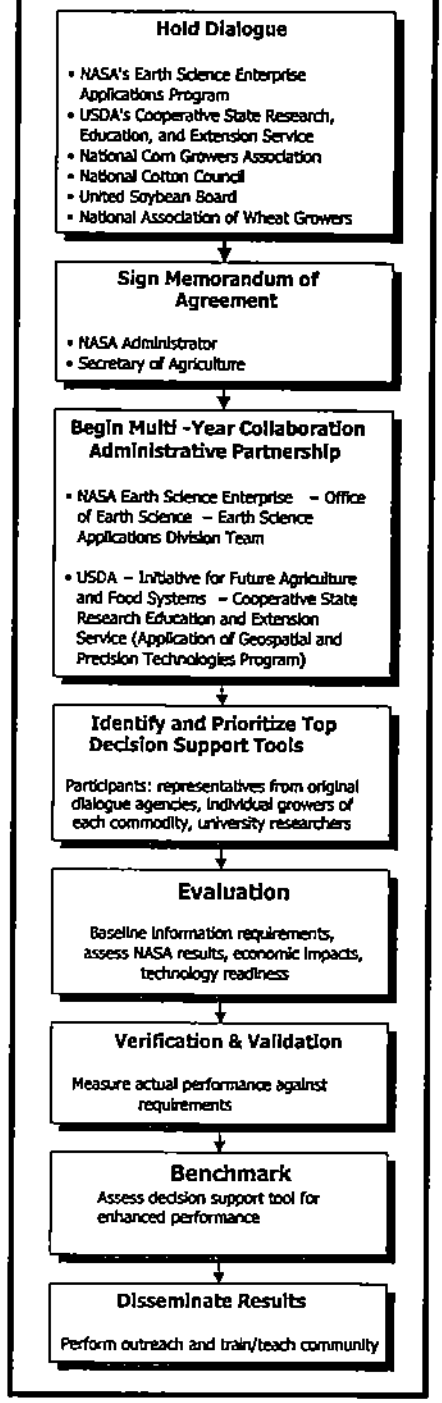
The implementation component of the Earth Science Enterprise Applications Program employs the functional steps of *evaluation*, *verification and validation*, and *benchmarking* in working to bridge the gaps from the research domain into the operational domain. Selected applications and related projects proceed through one or all of the following steps depending on the applications' maturity at the time of selection:

- *Evaluation*—evaluate the requirements for and technical feasibility of Earth science and remote sensing tools and methods for addressing national priorities for decision support in collaboration with partners.
- *Verification and Validation*—measure the performance characteristics of data, information, technologies, and/or methods, and assess the ability of these tools to meet the requirements for a particular application.
- *Benchmarking*—work with partners to enable and to document the adaptation and adoption of geospatial information tools and methods derived from ESE results to serve decision support in the national interest.

Adoption and transfer of project results will be enabled through extensive collaboration with partners in all steps to understand cultural, programmatic, and budgetary readiness of the partner to accept results. The Earth Science Enterprise Applications Program will support its partners' efforts to overcome barriers preventing successful adoption of project solutions.

At the conclusion of a successful project, the results of NASA Earth science research have been extended into operational use. At this juncture in the process, the partner organization will be utilizing NASA ESE results on a routine basis and their enhanced decision support tool will better support the decision and policy makers served by it. The value added by the assimilation of ESE results should provide measurable improvements in the life and property decision making of the partner organization and its customer base should also recognize value from the benefits of the operational use of Earth science in serving their decision-making processes. Figure 6 gives an example of the evolution of an ESE partnership program from conception through dissemination of results.

Figure 6 Partnership Framework Example: Agricultural Competitiveness National Application



3.5 Program Tactical Elements

The key tactical elements of the Earth Science Enterprise Applications Program include the following:

- Participate regularly and substantively in relevant Federal agency and interagency mechanisms that identify, assess, and develop plans to meet national needs using geospatial knowledge and information in decision support tools.
- Act as a bridge between forums and organizations that represent the operational community and the NASA leadership.
- Conduct workshops, publish articles, and maintain Internet sites to provide the community (Federal, state, local, tribal, academic, and private sector) with access to current and relevant information about applications of Earth system science.
- Coordinate with the ESSAAC and other relevant groups to review program direction and application selections.

- Contribute to, and benefit from, National Research Council studies and reports, and other relevant compendiums of information on opportunities and approaches.
- Develop detailed roadmaps that describe the NASA science and technology capabilities in relation to societal, economic, technical, cost, timing and other factors identified as relevant to realizing national application priorities.
- Continuously evaluate applications projects against predefined metrics and partner/user needs.
- Develop and maintain assessments of public and private sector Earth science and technology capabilities in databases that are readily accessible over the Internet.
- Sponsor science and technology assessments conducted by the National Research Council, as well as NASA-commissioned studies.
- In collaboration with the academic and research communities, and the public and private sectors, advance the state of knowledge and practice in measuring the value of applied geospatial knowledge and information in decision support tools.
- Issue competitive solicitations providing opportunities for the academic, public, and private sectors to contribute to realizing national applications.

4.0 Performance Evaluation

The Earth Science Enterprise Applications Program performance evaluation applied to NASA-sponsored application projects is based on the Government Performance and Results Act (GPRA) of 1993 (P.L. 103-62). Congress enacted the GPRA to promote comprehensive performance management throughout the Federal departments and agencies. The Program performance evaluation focuses on program inputs and outputs, desired outcomes, and expected impacts associated with the activity to transition Earth science and remote sensing technologies research towards operational use by service provider organizations. The Earth Science Enterprise Applications Program draws its inputs from the results of on-going ESE investments in Earth science and remote sensing combined with capabilities offered by the private sector and other public sector sources. The Program outputs are enhanced decision support tools, prototypes, assessments, and/or procedures resulting from the application benchmarking process. The Program outcomes are based on the extent to which the outputs are used in operational implementation on the national level. The Program impacts are socio-economic gains in efficiency and effectiveness associated with the operational implementation of the application.

The following are representative inputs, outputs, outcomes, and impacts for the Earth Science Enterprise Applications Program:

Inputs:

- Earth system science results, models, algorithms, predictions, and "lessons learned"
- Remote sensing mission data and derived information products
- Private sector capabilities in data supply and value added services
- Capabilities provided through public/private partnerships
- Basic and applied research from academia and government labs
- Partners in Federal, state, local, tribal with their national needs for knowledge and information (e.g., energy forecasts, early warning systems for human health impacts, community disaster preparedness, weather and climate prediction for agriculture)
- Requirements for decision support associated with national and/or international geographic areas
- Interoperability standards

Outputs:

- Decision support tools assimilating NASA ESE results (e.g., decision support systems, decision calendars, etc.)
- Prototypes, benchmarks and/or guidelines documenting demonstrated solutions for national priority applications

- Documentation of results of verification and validation evaluations for Earth science and remote sensing solutions
- Publication of results of applications research on potential for Earth science and remote sensing technologies to serve specific applications in the national interest

Outcomes:

- Operational use of NASA enabled solutions in the Federal, state, local, tribal and industry sectors that result in societal and economic benefits in the United States
- New and expanded market opportunities for the private sector to supply goods and services
- Expanding and sustained opportunities for academia to conduct research on continuously improving capabilities
- More efficient and effective government
- Demonstration of industry competitiveness resulting in opportunities of supplying applications solutions nationally and internationally

Impacts:

- Accelerate the integration of research and development results into operational systems
- Increase the breadth and scope of market opportunities for the private sector in the market areas of remote sensing and related value-added services
- Increase the breadth and scope of the research opportunities for the academic sector in the areas of Earth science and remote sensing
- Recognition for enabling the United States to be preeminent in the field of remote sensing and Earth science solutions
- Realize the potential societal benefits and economic savings that result from effective use of critical information and knowledge (projected to be in the billions of dollars)

Put simply, the key evaluation of performance is the degree to which the Program enables individuals and/or organizations in the public and private sectors to routinely deliver and use Earth science information that saves lives, that improves the quality of life, and that saves resources through improved decision making.

NASA measures the Earth Science Enterprise Applications Program's contribution to the NASA vision by assessing the degree to which effective applications of Earth science information *benefit the quality of life on Earth.*

5.0 Summary

This document describes the NASA Earth Science Enterprise Applications Program's vision, mission, and goals for the ten-year period from 2002 through 2012. It defines a program planning strategy to accomplish the vision, addresses a concept of operations for implementing the strategy, and identifies performance measures to evaluate the Earth Science Enterprise Applications Program. Specifically, the strategy document has shown an explicit architecture for assimilating Earth Science Enterprise research results into operational use in partner owned decision support tools (Figure 2). The architecture describes an end-to-end approach, based on systems engineering principles, for assimilating predictions and/or observations that will enhance the performance of a decision support tool. The decision support tools identified as targets for NASA research results are selected through a rigorous process and the assimilation of NASA results into these specific tools is deemed essential for National Applications that are of a priority to our nation. Since the decision support tools used in the National Applications will often affect life and property they must be thoroughly tested. Therefore, a well-defined process of evaluation, verification, validation, and benchmarking has been established to ensure the integrity of the enhanced tools. Finally, to provide the foundation for successfully accomplishing the mission of the Earth Science Enterprise Applications Program, a network of systems solutions has been developed. These include support teams with expertise and knowledge concerning missions and instruments, Earth system science laboratories, and Earth system science models.

As circumstances will likely change during the ten years of implementation, this document is intended to be a living one, sufficiently flexible to respond to changes in national policy and user needs, yet specific enough to provide guidance for applications projects and the overall program portfolio. The Earth Science Enterprise Applications Program welcomes comments regarding this document.

Appendix A – Glossary

Applications – specific use of results of science research, technology, data, information, knowledge, and/or modeling capability that serves a purpose.

Applied Research – research aimed at gaining the knowledge or understanding necessary to meet a specific, recognized need. (National Science Foundation)

Applications Demonstration – systematic approach to determine the viability of applying knowledge, data, and technology from research to meet operational requirements; implemented through the design and deployment of prototypes and processes in operational settings.

Assessments – *structured and systematic* appraisals of the state of science, technology, knowledge, and/or understanding of relevant capabilities, phenomena, or dynamics.

Benchmark – a standard by which a product can be measured or judged (i.e., How did the decision support tool that assimilated NASA observations and/or predictions compare in its operation, function, and performance to the earlier version?). The benchmarking process is required to support adoption of innovative solutions into operational environments that affect life and property.

Biogeophysical – of or relating to environmental assets essential to sustain human life that cannot be replaced or reproduced and for which there are no substitutes.

Decision Support System (DSS) – a computer based information-processing system for scenario optimization through multi-parametric analysis. A DSS utilizes a knowledge base of information with a problem solving strategy that may routinely assimilate measurements and/or model predictions in support of the decision making process. The DSS provides an interface to facilitate human inputs and to convey outputs. Outputs from a DSS would typically be used for making decisions at the local level and outputs from multiple DSSs may be used in establishing policy.

Decision Support Tools – a suite of solutions owned by NASA partners that are used in a variety of problem domains for decision and policy making. These solutions could include assessments, decision support systems, decision support calendars, etc.

Evaluation - the process that identifies decision support tools that have been developed by Federal agencies and other partners that are a priority to citizens of our nation and that can be enhanced by NASA ESE results. The specifications for how the candidate tool can be augmented by assimilating NASA ESE observations and predictions are developed through reverse engineering.

Framework – basic description of the relationships among elements in an operational environment that describes the mechanisms for how constituent technologies and institutional settings work together to meet a type of purpose.

Geospatial Data – information that identifies the geographic location and characteristics of natural or constructed features and boundaries of the Earth. This information may be derived from, among other things, remote sensing, mapping, and surveying technologies. (USGS)

National Spatial Data Infrastructure – the technology, policies, standards, human resources, and related activities necessary to acquire, process, distribute, use, maintain, and archive spatial data. (OMB)

Prototype – an initial scaled-down or limited-capacity version of a technique or system that is quickly developed to test the effectiveness of the overall design being used to solve a particular problem. This testing process is sometimes termed "rapid prototyping."

Reverse Engineering – the process through which NASA works with a partner to develop performance specifications for enhancing the partner's decision support tool by assimilating NASA ESE observations and predictions. These specifications are then translated into specific observations, predictions, and technologies and matched against existing NASA ESE results.

Roadmap – a system-level diagram depicting the progression of relevant science programs, technology developments and missions, and phases for an application related to a specific set of outputs and outcomes.

Standards – documented agreements containing technical specifications or other precise criteria to be used consistently as rules, guidelines, or definitions of characteristics to ensure that materials, products, processes, or services are fit for their purposes. (OMB)

Stakeholders – organizations that have a vested interest in the Program, including sources of requirements and beneficiaries of investments, products, processes, and services. Primary stakeholders include representatives of the Executive and Legislative Branches, public sector representatives from Federal, state, local, and tribal organizations; academic and research institutions; and the private sector.

Standards-based Data Products – packaged geospatial data and information generated to meet documented performance specifications in compliance with national standards. Data products are generally produced to enable interoperability and are independently verified and validated.

Validation – the process to ensure the technology-based solution (software, algorithm, model) effectively serves the functional requirements of the decision support tool.

Verification – the process of independently measuring the actual performance of a technology/system in terms of the performance specifications developed in the reverse engineering process (functional, performance, and design).

Appendix B – Abbreviations and Acronyms

DOD – Department of Defense

DOE – Department of Energy

DOI – Department of the Interior

DSS – Decision Support System

EOS – Earth Observing System

EOSDIS – Earth Observing System Data Information System

EPA – Environmental Protection Agency

ESE – Earth Science Enterprise

ESSAAC – Earth System Science & Applications Advisory Committee

FEMA – Federal Emergency Management Agency

GPRA – Government Performance and Results Act

HHS/NIH – Department of Health and Human Services and the National Institutes of Health

NIMA – National Imagery and Mapping Agency

NOAA – National Oceanic and Atmospheric Administration

OMB – Office of Management and Budget

OSTP – Office of Science & Technology Policy

USDA – U.S. Department of Agriculture

USGCRP – U.S. Global Change Research Program

USGS – U.S. Geological Survey

Appendix C – Program Directives

The Earth Science Enterprise Applications Program is provided direction from the Executive Branch and mandates and funding from the Legislative Branch. Agreements with Federal, state, local, and tribal agencies, international organizations, and the private sector also contribute to the direction of the Program. The entries in this appendix are intended to be representative and are not exhaustive.

Executive Management Direction

The Earth Science Enterprise Applications Program receives direction from national directives and policies. Executive Management sources of direction include PDD/NSTC-8, PDD-23 and OMB Circular A-16 and review from the Office of Management and Budget.

Driver	Response
Presidential Decision Directive NSTC-8 provides guidance on the goals of the U.S. space program, and assigns responsibilities to agencies in various space sectors. There is specific reference to Earth science and remote sensing. This directive assigns NASA as the lead agency for research and development in civil space activities.	NASA, in coordination with other departments and agencies, focuses its research and development in Earth observation to better understand global change and the effect of natural and human influences on the environment.
Presidential Decision Directive-23 provides direction to support U.S. industry technology leadership and to contribute to technology innovation in the remote sensing marketplace.	NASA evaluates the potential for U.S. commercial remote sensing sources to address the requirements for standard information products that serve the national interest.
OMB Circular A-16 describes geospatial data as "a national capital asset." The Circular provides for improvements in spatial data coordination and for the use of geographic data for the benefit of the government and the Nation. Applications using spatial data that adhere to Federal Geographic Data Committee standards are identified to "enable cost effective public and private policy development, management and operations."	The Earth Science Enterprise Applications Program is represented on the Steering Committee and the Coordinating Committee for the Federal Geographic Data Committee. ESE provides applications research of candidate remote sensing technologies, through to verification and validation and applications demonstration in support of providing global data sets that are National Spatial Data Infrastructure compliant.

Congressional Mandates

Driver	Response
Global Climate Change Act of 1990 has the objective of determining the origins, rates, and likely future course of national and anthropogenic changes.	ESE contributes evaluation, verification, and validation through to demonstration of remote sensing solutions from the public, private, and foreign sectors to support global climate change research.
Commercial Space Act of 1998 and subsequent legislation directs NASA to establish a long-term plan to promote scientific applications of U.S. commercial remote sensing capabilities through the purchase of data, development of applications, and collaboration with industry, research universities, and other government agencies.	NASA systematically evaluates the potential for private sector data and services to address information product needs that are in the national interest.

NASA Guidance
NASA and the Earth Science Enterprise provide guidance to the Program in the form of Acts, Plans, and Agreements.

Driver	Response
National Aeronautics and Space Act endeavors to preserve the United States as a leader in aeronautical and space science and technology and in the applications thereof.	ESE contributes to preserving the U.S. as a leader in this area by accelerating the connection between national priority needs for spatial information and Earth science solutions.
Earth Science Enterprise: ***Research Strategy*** provides scientific results to answer the science questions that are the underpinning of the Earth Science Enterprise Applications Program.	The Earth Science Enterprise Applications Program addresses the potential of specific research, including carbon cycle science, tropospheric winds, and ocean color measurements, to meet applications needs in the national interest.

Agreements
The Agency, the Enterprise, and the Lead Center for Applications have executed a number of formal agreements that link the Earth Science Enterprise Applications Program to important strategic commitments. These agreements provide specific sources of national- and international-level strategic and implementation guidance to the Program. They incorporate implementation options that include all levels of government, the private sector, and the general public.

Driver	Response
Supply relevant remote sensing and related applied research, technology and development in exchange for requirements knowledge and insight into practice improvements. **(USDA, USGS)**	NASA-USDA collaboration is carried out through implementation of a NASA Research Announcement for Agriculture, Forest and Rangeland Management.
Conduct collaborative projects whenever they fulfill shared requirements, offer cost savings, increase agency capability, improve knowledge, or improve environmental data and information. **(NOAA Basic Agreement)**	Specific sub-agreements have been made between the agencies for the design, development, test and evaluation of the next generation of polar orbiting and geosynchronous instruments and systems. The Program works with NOAA to determine an optimal means to fulfill shared application requirements.
Undertake cooperative calibration and verification and validation activities that benefit the nation in terms of public and commercial satellite and airborne sensor systems **(DOD, DOE, FEMA, NOAA, Scientific Data Purchase)**, and validate commercial remote sensing products and spatial information technologies for application to national transportation infrastructure development and constraints. **(Department of Transportation)**	ESE evaluates Scientific Data Purchase products and supports the Joint Agency Commercial Imagery Evaluation (JACIE) group composed of NASA, Stennis Space Center, the National Imagery and Mapping Agency, the U.S. Geological Survey, and selected academic institutions.
Collaborate on joint research and technology projects that meet the emerging geospatial information needs of the 21st Century. **(DOI, USGS)**	ESE supports research and technology requirements of USGS plan for ***The National Map***.

Appendix D – References

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Appendix E – NASA and Earth Science Enterprise Web Sites

National Aeronautics and Space Administration	http://www.nasa.gov/
NASA Vision	http://www.nasa.gov/bios/vision.html
NASA Strategic Plan	http://www.hq.nasa.gov/office/codez/plans/pl2000.pdf
NASA Earth Science Enterprise	http://www.earth.nasa.gov/
NASA Earth Science Enterprise Strategic Visions	http://www.earth.nasa.gov/visions/index.html
NASA Earth Science Applications Directorate	http://www.esa.ssc.nasa.gov
Earth Science Applications Network	http://www.esnetwork.org